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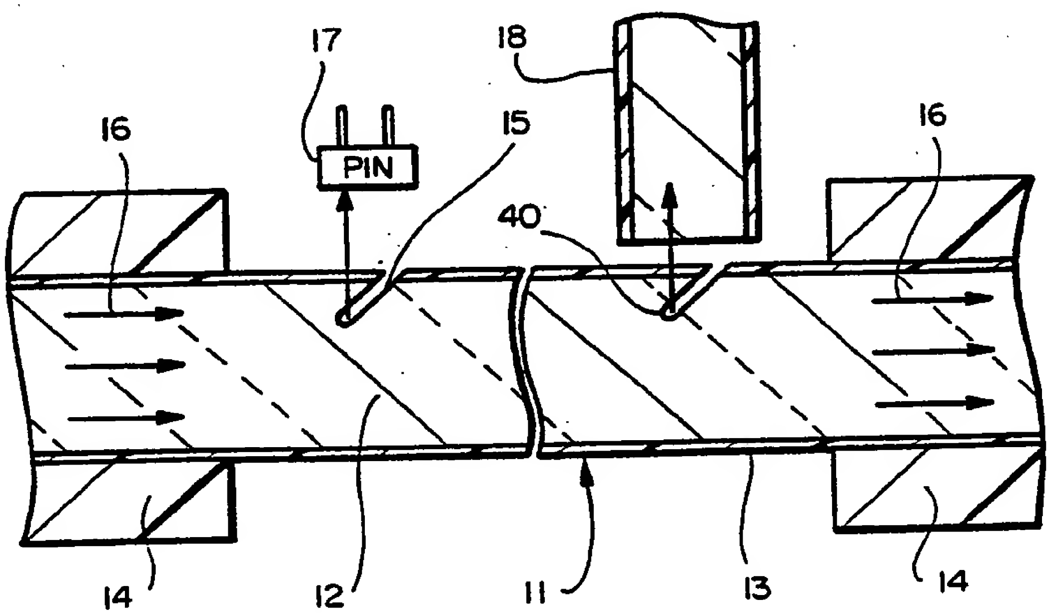
(54) Title: METHOD OF DEFORMING A POLYMER OPTICAL FIBER TO FORM TAPS



(57) Abstract

A method of forming passive couplers or taps for a polymer optical fiber (11) includes heating a knife (23) and urging the heated knife against a side (13) of the optical fiber so as to make a cut (15) in an intermediate portion of the fiber at an angle so as to allow either reading, writing and/or sensing thereat.

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METHOD OF DEFORMING A POLYMER OPTICAL FIBER TO FORM TAPS

Cross-References to Related Applications

The present application is related to U.S. patent application entitled "Optical Fiber connector Structure" invented by Frank H. Levinson, filed concurrently herewith, the disclosure of which is incorporated herein by reference.

Background of the Invention

The present invention relates to methods of forming a coupler or tap for a polymer optical fiber, methods of using such couplers, and articles produced thereby.

Optical couplers or fibers transmit information in the form of light signals much as electrical signals represent information transmitted in copper wire or cable. Glass optical conductors have received the most attention in the last several years as they have been developed to have very low attenuations and extremely high bandwidths; their use in certain telephone situations today results in enormous costs and reliability savings as compared to copper conductors. Polymer optical conductors differ from glass optical conductors in that the conductor and cladding is made of a polymer, typically poly-methyl-methacrylate (PMMA) or polystyrene, whereas glass optical conductors include cores and claddings which are generally made of silica glass, e.g. SiO_2.

Though glass optical conductors exhibit far greater bandwidth capabilities than polymer optical fibers and have dramatically lower attenuations, in many applications polymer optical fibers are better suited to meet information transmission

needs than glass optical fibers in view of the reduced craft sensitivity associated with working with polymer optical fibers. Specifically, cores of polymer optical fibers are generally much larger than cores of glass optical conductors, e.g. polymer optical conductors typically have core diameters, anywhere between 200 and 1000 microns whereas glass cores have diameters of around 7 to 200 microns, and accordingly polymer optical conductors are easier to handle and align when interconnecting. In addition, polymer optical conductors are easier to cut than their glass counterparts.

Accordingly, especially in platform applications where a length of the transmission media does not exceed a few hundred meters, the relatively low bandwidth capability and high attenuation associated with polymer optical fibers are not overly critical making polymer optical fibers a preferred choice over glass optical fibers and metal conductors such as copper.

Nevertheless, a problem exists in the art of polymer optical fiber networking in that connectors and couplers for polymer optical fibers tend to be unduly lossy, e.g. high in attenuation, which unduly restricts the use of and benefits of polymer optical fibers. Typically, polymer optical fiber connectors have attenuations in the range of 1-3 dB (20-50 per cent) which renders bus and ring architectures undesirable since only a very limited number of couplers can be attached thereto with typical light flux budgets.

Summary of the Invention with Objects

Accordingly, it is an object of the invention to eliminate the above-noted difficulties and to provide a method of forming a polymer optical fiber coupler which has a very low attenuation

and which is extremely craft easy to form by unskilled workers, especially in a field situation.

These and other objects of the invention are achieved by a method of forming an optical coupler for a polymer optical fiber, comprising the steps of:

heating at least one of a fiber deforming element and an intermediate portion of a preformed solid optical fiber comprising a polymer core surrounded by a polymer cladding; and

urging the deforming element against a side of the optical fiber intermediate portion so as to deform the fiber cladding and form a void in a side of the core which extends only partially through the core.

These and other objects of the invention will be further understood by reference to the accompanying drawings.

Brief Description of the Drawings

Figure 1 illustrates an optical read T-tap formed using a hot blade and alignment tool method of the invention;

Figure 2 illustrates a tap similar to figure 1 which is used for writing as opposed to reading;

Figures 3a-3d illustrate preferred method steps of making the taps of figures 1, 2;

Figures 4-6 illustrate further preferred tap constructions;

Figure 7 illustrates a preferred method of making the tap of figure 4;

Figures 8-11 illustrate preferred networks constructed using taps created according to the invention.

Description of the Preferred Embodiments

The invention comprises uses, means and methods for the coupling, injecting and extracting of light modes within a multimode optical fiber to be used in a distribution manner for information transfer purposes.

Optical fibers are broadly classified into two types, the first being single mode and the second being multimode. Whereas single mode fiber only supports a single mode, referred to as the fundamental mode, multimode fiber supports a plurality of modes, generally of the order of 1,000-10,000 or more. Multimode fiber can be either graded or step index, and can include a core and cladding which are made of glass, polymers or a combination thereof. Preferred embodiments of this invention relates to the use of step index multimode fibers which have both the core and cladding composed of polymer materials.

Polymer based optical fibers can have the property that their shapes, sizes and surfaces can be modified through the use of forming, molding or cutting tools after the fiber has been manufactured. Devices formed by such techniques might not be so readily formed in glass optical fibers since the softening temperature of the glass fibers is about 2000°C as opposed to that of the plastic fibers which can soften below 200°C. The various embodiments of this invention are devices and methods for forming such devices through modifying a solid polymer fiber after it has been manufactured, e.g. drawn from a preform.

Figure 1 illustrates an optical T-tap formed using a hot blade and alignment tools. Optical fiber 11 having an optical core 12 and cladding 13 and a cable sheath or jacket 14 has a flat incision 15 placed into it by means of a hot forming blade. The incision 15 is filled with air and penetrates the fiber to a depth less than the fiber diameter. For example, in a fiber with a 1000 micron outer diameter and a cladding thickness of 10 microns, the incision depth could be less than 50, 100, 200, or 300 microns, preferably being about 250 microns. In relative terms, the depth is less than 5%, 10%, 20%, or 30%, preferably between 10-25%. A light ray 16 propagating in the fiber either passes by the incision 15 or is deflected up by total internal reflection off of the polymer-air interface to a photodiode 17 or second optical fiber 18. The incision forms an angle with a longitudinal axis of the fiber, the angle preferably being between 30 and 60°, preferably 45°.

A similar structure can be used to inject light into a fiber. Figure 2 illustrates an optical fiber T-tap identical to figure 1 but which is used to inject light into the fiber from an external light emitting device 19 or fiber 20. Light reflected by the incision is directed along the fiber axis and quickly diverges to equally fill the entire fiber cross section.

The structure illustrated in figures 1 and 2 is made by using a hot knife or other thin blade to melt and locally form the fiber into the desired shape. Preferably the knife, blade, or other tool used for deforming the fiber is first coated with a lubricant, e.g. silicone oil, to insure no sticking between the tool and so as to ensure the formation of a highly polished finish.

Figure 3 illustrates a preferred forming process as the cabled fiber is (a) first centered stripped by a series of two ring cuts 31 and two length cuts which removes portions 32 of the

protective jacket from the fiber, (b) then the cable fiber is mounted into a protective structure 21 which is crimped at 22 onto the cable jacket and supports the optical fiber, (c) at this point a hot forming blade 23 with a heat source 24 is aligned with respect to the fiber and the recently affixed protective structure using a tool 25 and the incision is made, and finally (d) an active device 26 or fiber can be inserted into and mounted onto the protective structure using the same alignment features which referenced the incision placement. Such a process guarantees the alignment of the formed optical surface to the active device or pick-up fiber.

T-taps formed in this manner have demonstrated an ability to couple up to 10% of an LEDs total output power while exhibiting a throughput loss less than 0.3 dB.

Figure 4 illustrates an optical T-tap which has an incision or notch 27 in this case on the opposite side of the fiber from the active device 28 or fiber 29. This T-tap can be formed either through the hot knife technique described above or by means of an abrasive removal of material from the area followed by a final polishing of the region using a fine grit surface.

Referring to figure 7, the abrasion of the surface is accomplished by dragging a file 51 or other abrasive surface across the fiber in proximity to a trough 52 that exists in T-tap body 53 which has been fastened around the fiber and cable for guiding the file. As the groove is formed the abrasive tool only cuts the fiber to the shape and depth allowed by the trough in the T-tap body 53. Thus the tap body serves as a protective and forming structure and then as a mirror alignment structure simultaneously since one side wall of the trough is mirrored. Such a trough can also be used to guide the knife or blade of the prior embodiments.

Figure 5 illustrates an optical T-tap which is bidirectional; the light injected into or removed from the fiber travels in both directions along the fiber axis; in this case the incision 29 has a symmetrical form. T-taps formed in this manner have demonstrated an ability to couple up to 20% of a LEDs total output power while exhibiting a throughput loss less than 0.3 dB.

Figure 6 illustrates an optical T-tap which is bidirectional and uses a mirror element 41 molded as part of a base piece 42 to deflect the beam rather than the polymer-air interface/total internal reflection surface; optical gel 43 fills any space between the fiber incision and the mirror element. This mirror element with its optical gel can be used to clear the polymer surface that may have been left "frosted" in appearance due to the method employed to remove the fiber material, for example, if an abrasion technique was used.

Operation of each of these T-taps is similar. Light propagates down the fiber core and is confined inside the fiber cladding. The T-tap incision occludes a portion of the fiber core cross section, typically 5-10% and the light striking the surface of the incision is directed. The remainder of the light continues past the T-tap.

According to the invention, since the blade, knife, or other type of tool is preferably heated to a temperature which is at least equal to or greater than a softening temperature of a material forming the fiber, e.g. its core and cladding, the tool thus "deforms" a side of an intermediate portion of the fiber. Depending on the shape of the deformation thus formed, the fiber cladding 13 may either form a continuous and unbroken indentation or void which extends partially within the core as illustrated in figure 4, or the fiber cladding may be locally

deformed to such an extent so as to actually be pierced at a region 40 as illustrated in figure 1. All such embodiments are intended to be included within the scope of the invention. Accordingly, it should be understood that the blade, knife, or tool thus functions to form a void in a side of an intermediate portion of the optical fiber which extends only partially within the fiber, e.g. only 10, 20, or 30% of a distance of an undeformed diameter of the core so as to form an indentation which can either be completely covered by a thinned out section of the cladding or only partially covered by a thinned out section of the cladding such that a portion of the core is also exposed.

Figures 8-11 illustrate various network configurations rendered usable by the present invention. Referring to figure 8, a read bus 61 includes a plurality of taps or couplers as described which each withdraw a portion of an optical signal from a read bus optical fiber, with reference numeral 62 illustrating a write bus whereby a plurality of taps or couplers as described serially inject an optical signal into an optical fiber. Figure 9 illustrates an architecture whereby read and write taps are interleaved so as to enable a drop-insert protocol to be utilized if desired. Finally, figure 10 illustrates the use of taps as described in a sensor network, with figure 11 illustrating one preferred embodiment whereby an element to be sensed such as a tuning fork 64 has a reflective surface 65 thereon which reflects light withdrawn from the fiber by one of the taps of the invention back into the fiber. According to this example, the tuning fork would change frequency with changing temperature, and the frequency can be detected by detecting the injected light by using a detector 66 as an end of the sensing network. These taps of the invention for sensors are advantageous since a very large proportion of the reflected light from the elements 64 being sensed can be reinjected into the fiber while at the same time each sensing node induces a minimal attenuation to the fiber light.

Though the invention has been described by reference to certain preferred embodiments, the invention is not to be limited thereby and only by the appended claims.

CLAIMS

1. A method of forming an optical coupler for a polymer optical fiber, comprising the steps of:

   heating at least one of a fiber deforming element and an intermediate portion of a preformed solid optical fiber comprising a polymer core surrounded by a polymer cladding; and

   urging the deforming element against a side of the optical fiber intermediate portion so as to deform the fiber cladding and form a void in a side of the core which extends only partially through the core.

2. The method of claim 1, the void extending within the core by a maximum linear distance less than 20% of an undeformed diameter of the core.

3. The method of claim 1 or 2, the deforming element being urged so as to deform a shape of the cladding such that the cladding is pierced by the deforming element.

4. The method of claim 1, 2 or 3, the deforming element being urged so as to deform a shape of the cladding such that the cladding remains continuous and unbroken throughout an area of the void.

5. The method of any one of claims 1-4, further comprising the step of removing the cutting element from the fiber intermediate portion subsequent to deforming the fiber portion.

6. The method of any one of claims 1-5, further comprising the step of leaving the deforming element in contact with the fiber intermediate portion subsequent to deforming the intermediate portion so as to substantially fill the void thereby.

7. The method of any one of claims 1-6, further comprising the step of orienting the deforming element at an angle to a longitudinal axis of the optical fiber as the deforming element is urged against the fiber intermediate portion, the angle being between 30° and 60°.

8. The method of any one of claims 1-7, further comprising the step of disposing an electro-optic transducer adjacent the optical fiber intermediate portion.

9. The method of any one of claims 1-8, further comprising the step of disposing a light waveguide adjacent the fiber intermediate portion and disposing an electro-optic transducer adjacent an end of the waveguide.

10. The method of any one of claims 1-9, only the deforming element being heated directly by a heat source.

11. The method of any one of claims 1-10, further comprising the step of disposing a reflecting layer on a surface of the void formed by the cutting element.

12. The method of any one of claims 1-11, further comprising the step of filling the void within the core created by the deforming element.

13. The method of claim 12, the void being filled by placing the fiber portion on a fixture which includes a protrusion extending therefrom which fills the notch, the protrusion including an index matching gel thereon.

14. The method of any one of claims 1-13, the deforming element including a waveguide, further comprising the step of allowing the fiber intermediate portion to cool with the waveguide disposed partially only within the fiber core so as to bond the waveguide to the optical fiber intermediate portion and fill the void.

15. A method of forming an optical coupler for a polymer optical fiber, comprising the steps of:

abraiding an intermediate portion of an optical fiber with an abrasive tool such that a void is formed in a side of the fiber so as to extend only partially within a core of the fiber, the fiber comprising a polymer core and a polymer cladding.

16. The method of claim 15, further comprising the step of filling the void.

17. An optical fiber network, comprising:

a polymer optical fiber comprising a polymer core surrounded by a polymer cladding;

a plurality of taps disposed linearly along the fiber, each tap being formed by heating at least one of a deforming element and an intermediate portion of an optical fiber; and

urging the deforming element against a side of the optical fiber intermediate portion so as to form a void in the fiber intermediate portion which extends only partially within the core.

18. The network of claim 17, the taps comprising read taps arranged serially on the fiber.

19. The network of claim 17 or 18, the taps comprising write taps arranged serially on the fiber.

20. The network of claim 17, 18 or 19, the taps alternately comprising read and write taps disposed serially on the fiber.

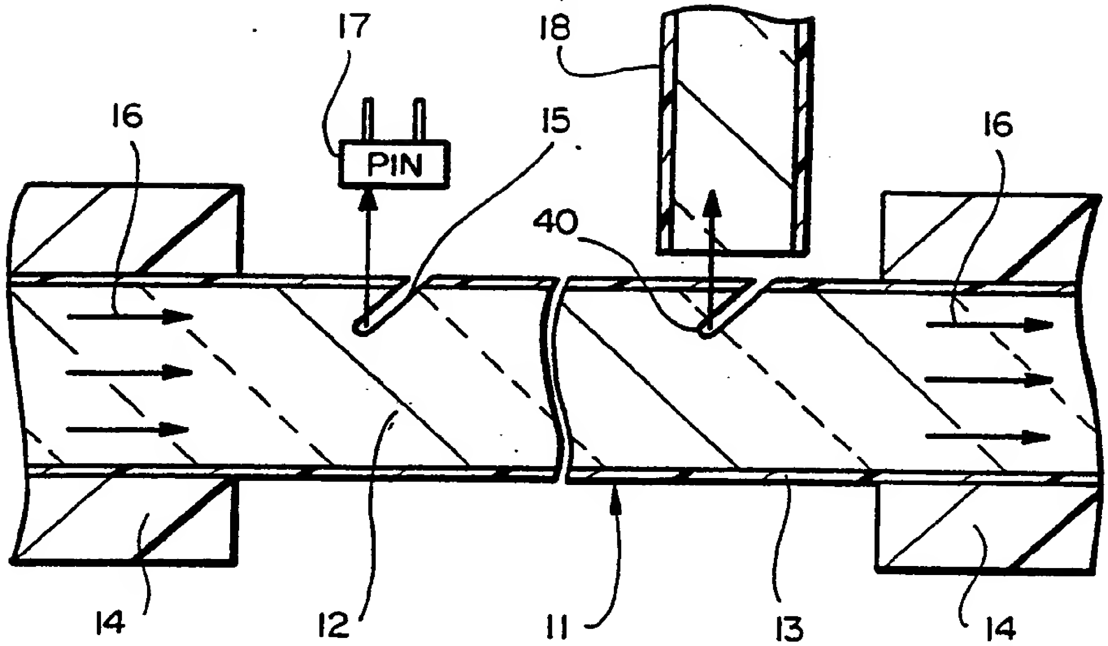

FIG_1

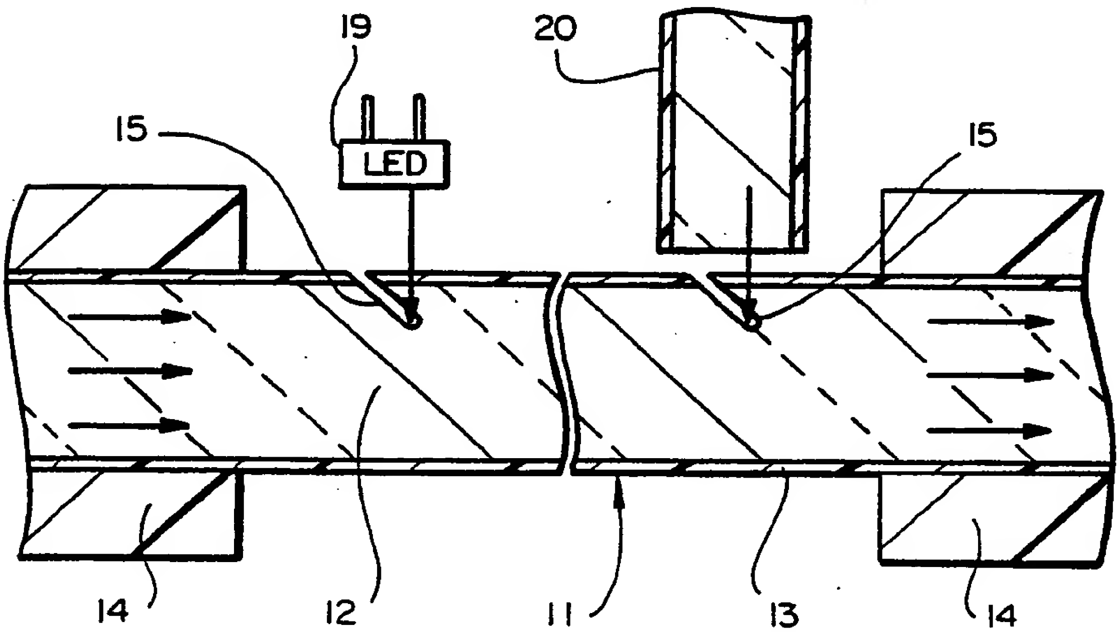

FIG_2

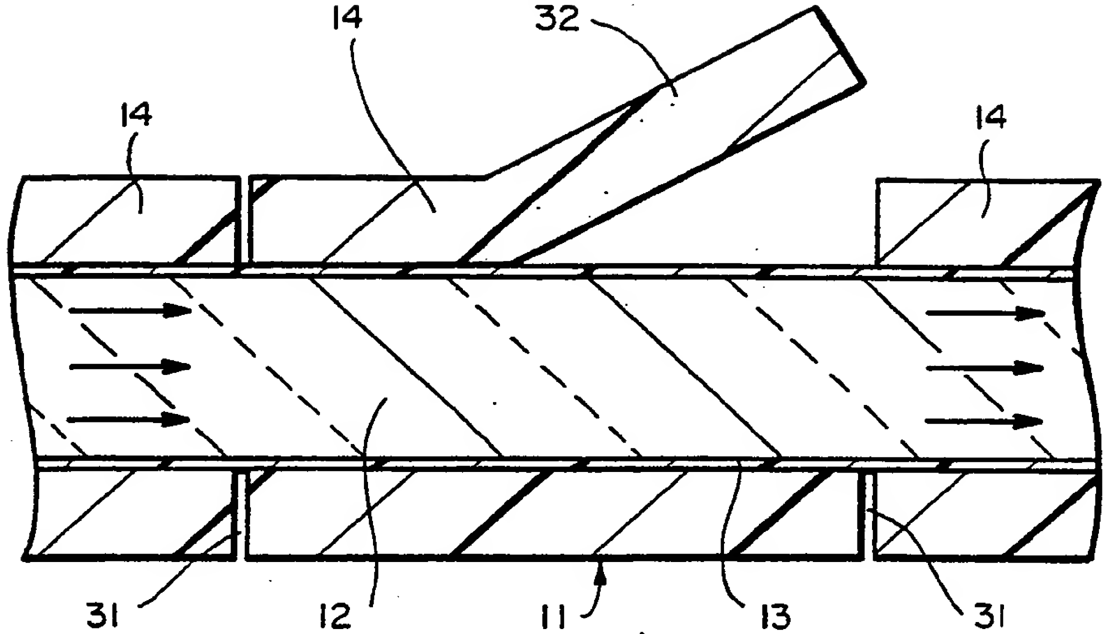

FIG_3a

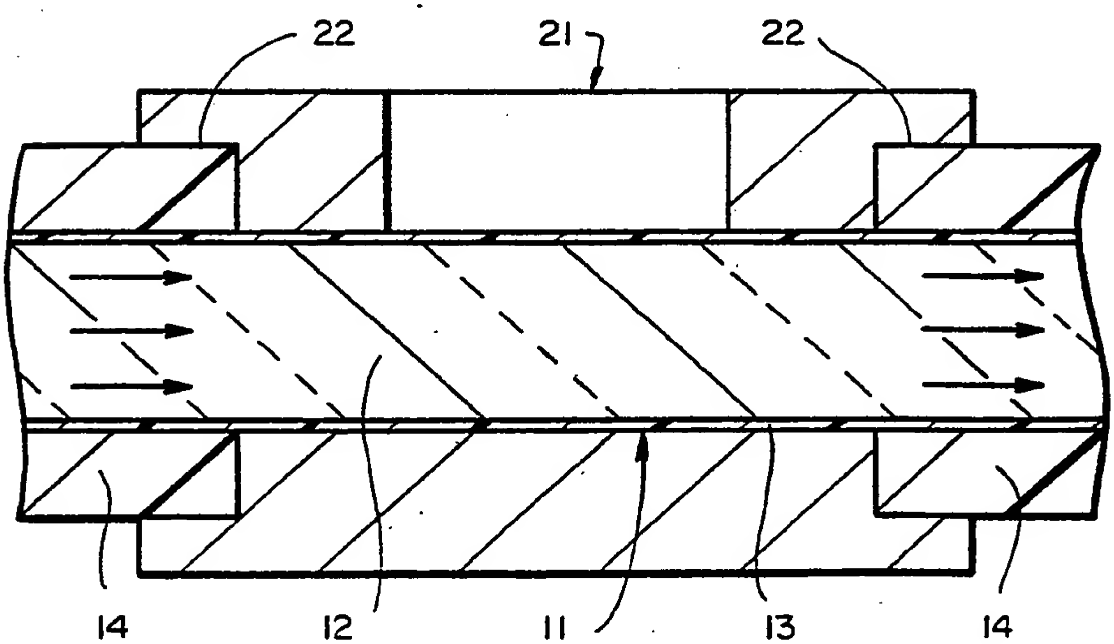

FIG_3b

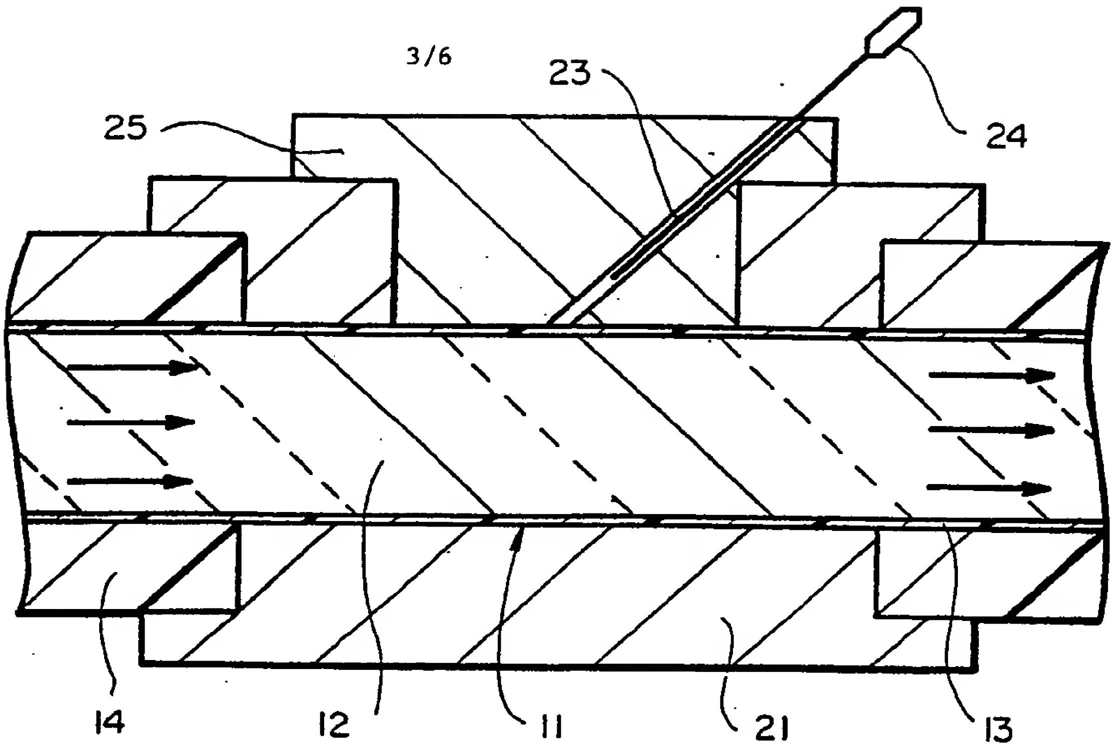

FIG_3c

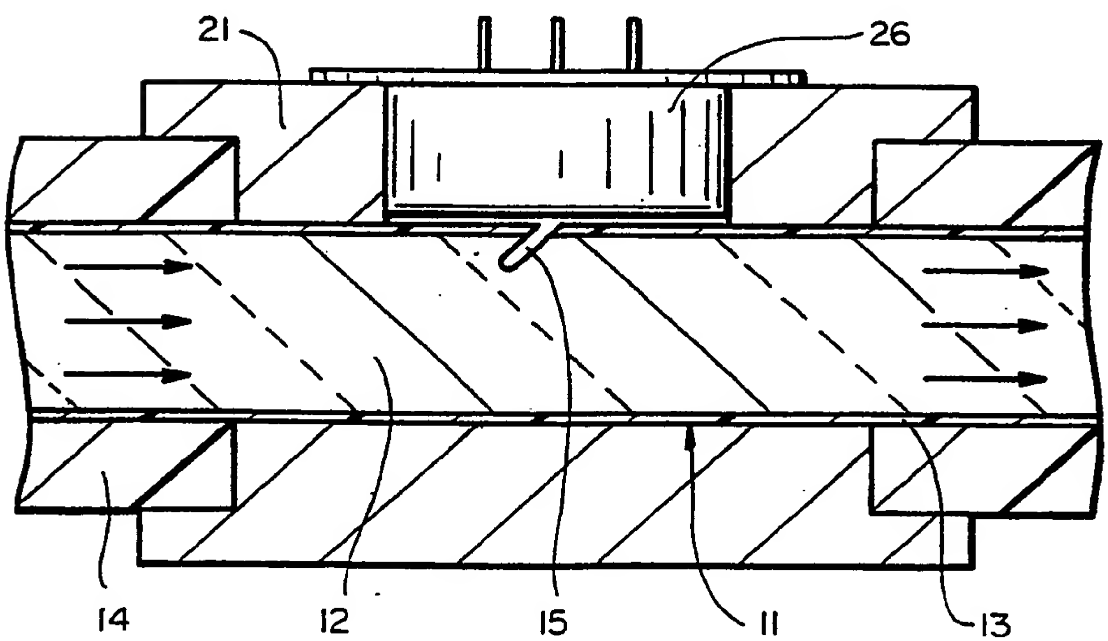

FIG_3d

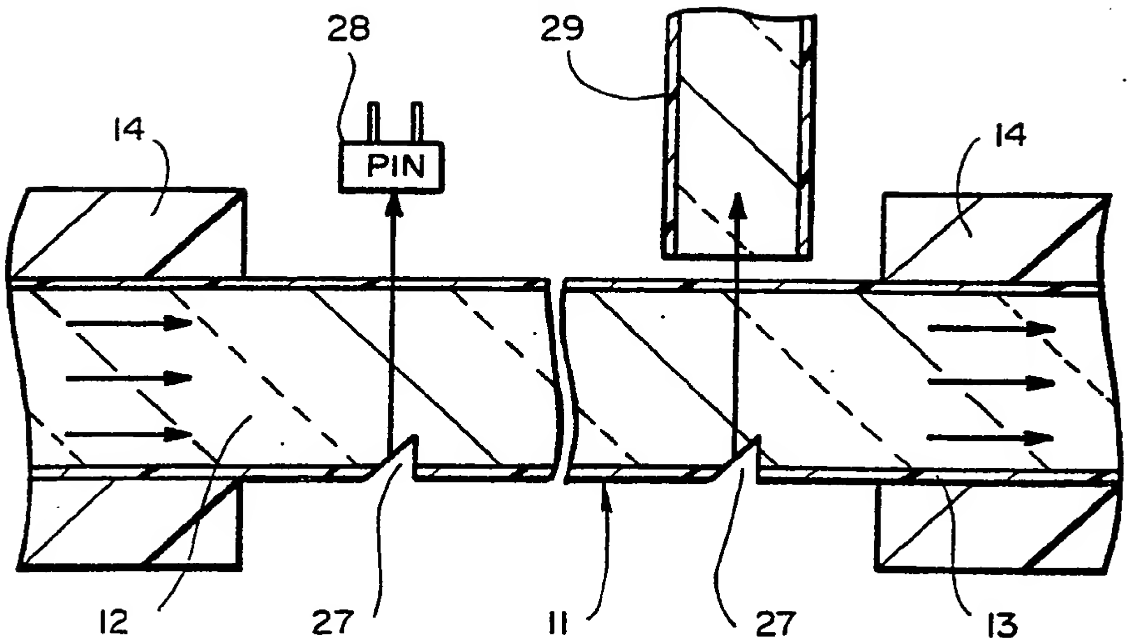

FIG_4

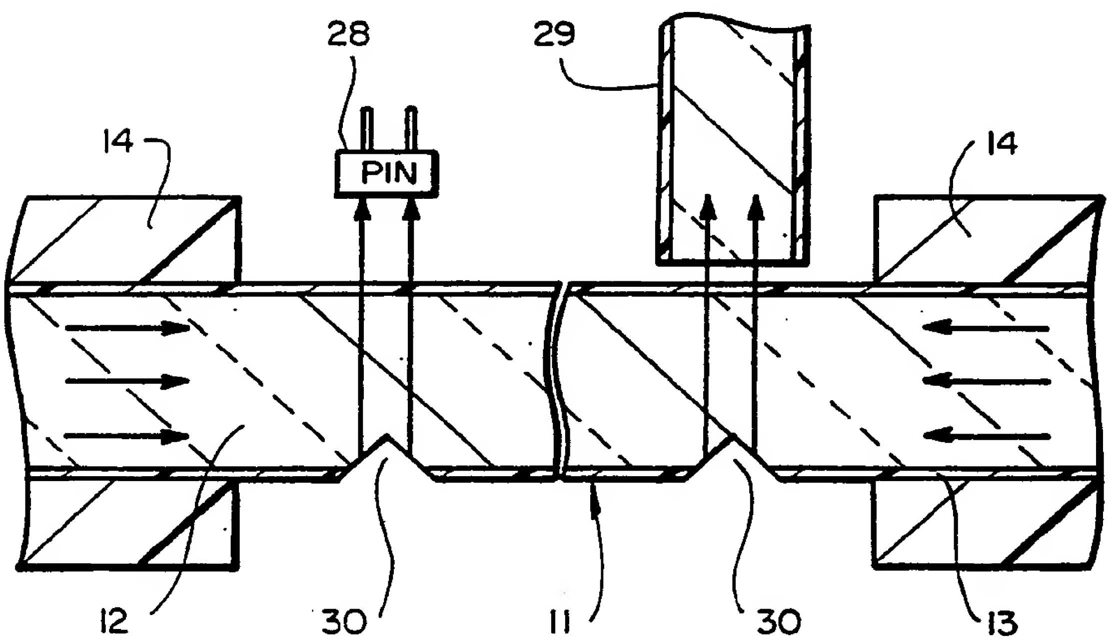

FIG_5

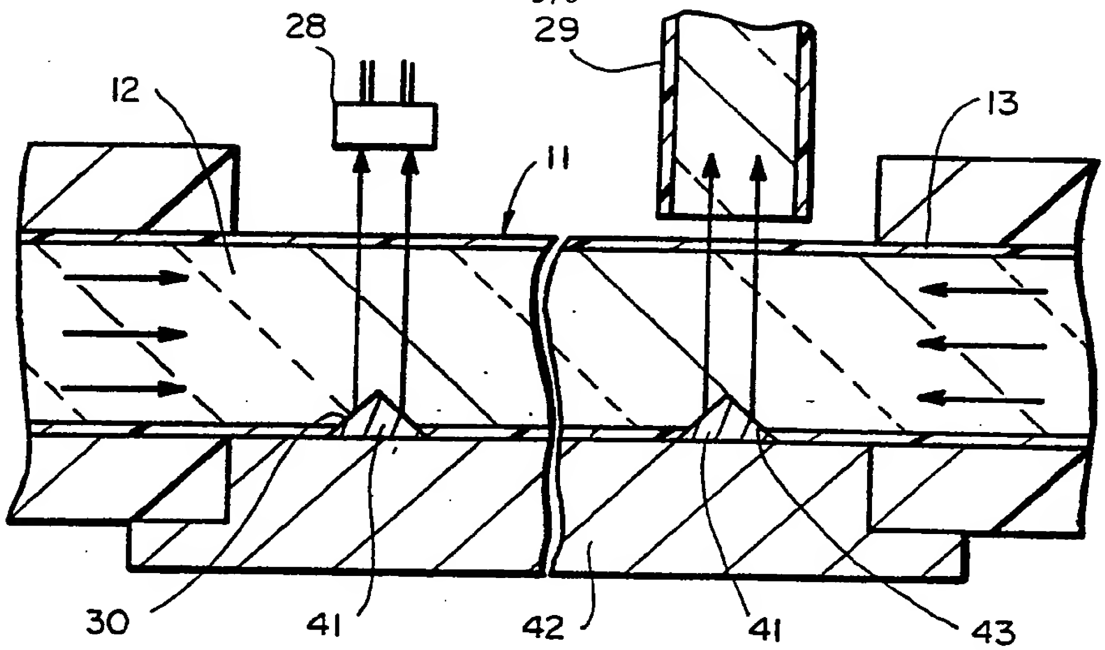

FIG_6

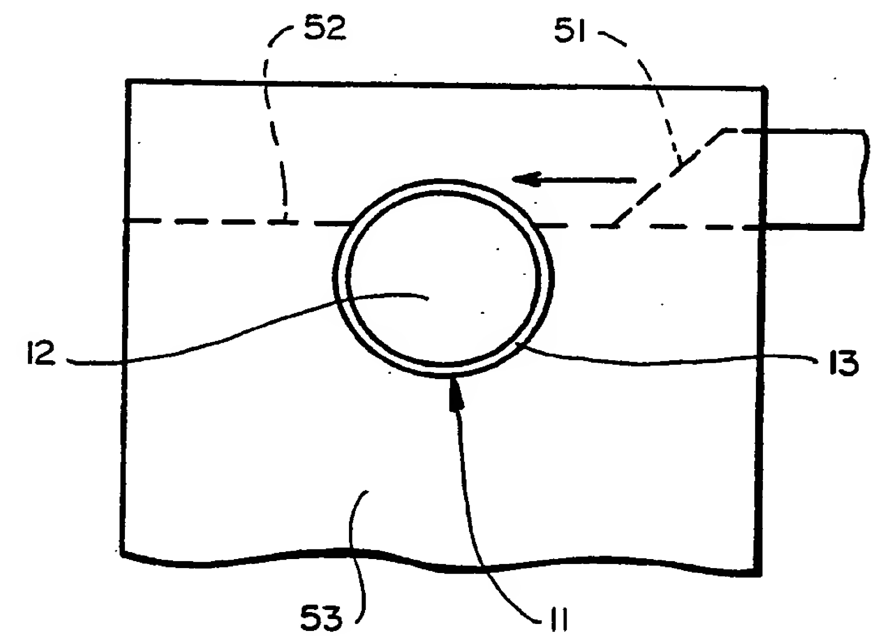

FIG_7

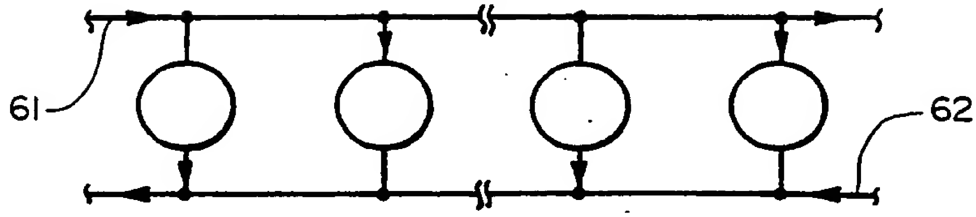

FIG_8

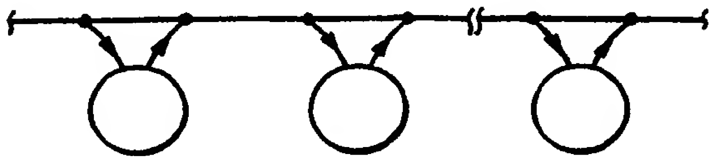

FIG_9

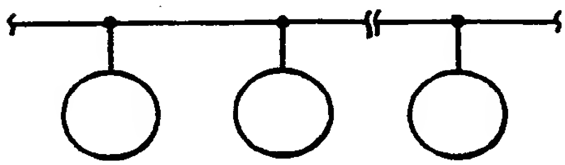

FIG_10

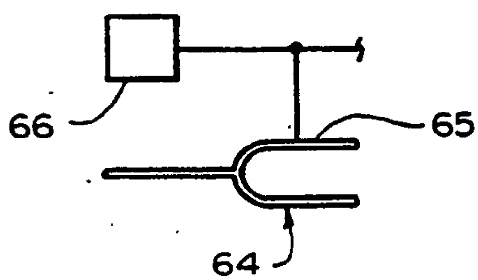

FIG_11

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 89/03251

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: G 02 B 6/28, 6/42

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC5	G 02 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	EP, A2, 0271177 (ENSIGN-BICKFORD OPTICS CO) 15 June 1988, see page 7, line 8 - line 14; page 7, line 35 - line 37 --	1-20
Y	US, A, 4307932 (WINZER) 29 December 1981, see column 3, line 4 - line 13; figure 1B --	1-5
Y	US, A, 4712858 (PRESBY) 15 December 1987, see abstract; figure 1 --	1-20
Y	Patent Abstracts of Japan, Vol 10, No 305, P507, abstract of JP 61-120109, publ 1986-06-07 SONY CORP --	1-16

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
2nd January 1990	19. 01. 90
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	T.K. WILLIS

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

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ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. PCT/US 89/03251

SA 31671

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
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